# A METHOD AND SYSTEM FOR MULTI-CHANNEL RF DIGITIZATION WITH ANALOG SELECTIVITY

## Technical Field

[0001] The present invention relates generally to a digital RF receiver, and more particularly to a digital RF receiver capable of simultaneously serving multiple users.

## Background Of The Invention

[0002] The conventional approach to simultaneously receiving multiple channels in a receiver is to simply provide multiple receivers, with a separate receiver assigned for each channel. Each additional receiver carries a penalty in terms of cost, weight, power and space requirements for additional hardware.

[0003] An alternate approach is to digitize the full range of a particular band of frequencies, and use digital signal processing (DSP) after digitization to process channels in the band. This approach may reduce the penalties described above. However, the capability is beyond currently available analog-to-digital converter (ADC) technology. Therefore, multiple ADC's are required to digitize multiple channels in a band.

[0004] A method has been proposed for providing multiple simultaneous access to signals within a band that are widely separated in frequency using a single ADC. The separate signals are translated in frequency so that they form a single, generally continuous composite band thereby eliminating the wide frequency gap between the signals. However, the translation requires mixing and filtering the different signals and a local oscillator for each signal. Dividing at least one band into portions that are overlapped further reduces the bandwidths. Thus although one ADC may be used, the additional hardware required for each signal does not reduce the overall cost and complexity associated with multiple ADC's.

## Summary Of The Invention

[0005] It is an object of the present invention to provide digitization of a predetermined number of channels within a complete band of RF channels to allow simultaneous processing of more than one channel.

[0006] It is another object of the present invention to reduce the bandwidth before digitization using multiple independently tunable bandpass filters with outputs that are combined to form one signal for digitization.

[0007] Still a further object of the present invention is to absorb strong undesired channels that could overload the receiver system.

[0008] In carrying out the above objects and other objects and features of the present invention, multiple tunable bandpass filters are used for the particular RF channels to be processed. The filter outputs are combined to form one signal for digitization.

[0009] Other objects and advantages of the present invention will become apparent upon reading the following detailed description and appended claims, and upon reference to the accompanying drawings.

## Brief Description Of The Drawings

[0010] For a more complete understanding of this invention, reference should now be had to the embodiments illustrated in greater detail in the accompanying drawings and described below by way of examples of the invention. In the drawings:

[0011] FIGURE 1 is a block diagram of the present invention for processing a received RF signal for multiple users; and

[0012] FIGURE 2 is a circuit diagram of one embodiment of the block diagram shown in Figure 1;

[0013] FIGURE 3 is a graph of the antenna power for two frequencies;

[0014] FIGURE 4 is a graph of the output power at the first tunable bandpass filter tuned to a first frequency;

[0015] FIGURE 5 is a graph of the output power at the second tunable bandpass filter tuned to a second frequency;

[0016] FIGURE 6 is a graph of the output power for simultaneous tuning of two bandpass filters to the same frequency according to the present invention;

[0017] FIGURE 7 is a graph of the output power for tuning of two bandpass filters to different frequencies according to the present invention;

[0018] FIGURE 8a is a graph of the air signal strength of two separate frequencies at the antenna;

[0019] FIGURE 8b is a graph of the power output at the first tunable bandpass filter;

[0020] FIGURE 8c is a graph of the power output at the second tunable bandpass fitler;

[0021] FIGURE 8d is a graph of the power output after a first automatic gain control;

[0022] FIGURE 8e is a graph of the power output after a second automatic gain control;

[0023] FIGURE 8f is a graph of the power output provided to the receiver; and

[0024] FIGURE 9 is a flow chart of the method of the present invention.

## Detailed Description Of Preferred Embodiments

[0025] The present invention is described herein with reference to a complete band of frequencies for a particular mode of communication, such as frequency modulation (FM) channels. It should be noted however, that the present invention is applicable to other bands and frequencies as well. One skilled in the art is capable of translating the present invention to other modes. Figure 1 is a block diagram of the system 10 of the present invention. An antenna 12 receives a complete band for a particular mode of communication, for example FM. A plurality of tunable bandpass filters 14 are provided for selecting a desired channel. The bandpass filters 14 may all operate on the same broadcast band, i.e. AM or FM, but are capable of independently tuning to a specific channel. The outputs of the bandpass filters 14 are combined at a summer 16 to form one signal for digitization at a single ADC 18.

[0026] The digitized signal is sent to a digital signal processor 20 where the selected channels 22 are independently processed to provide usable signals, such as audio or data signals, to users in the vehicle. Examples of users include, but are not limited to, vehicle occupants that are listening to the radio, or devices for data handling such as RDS.

[0027] First, the present invention allows for tuning to one received frequency to improve the signal-to-noise ratio prior to analog to digital conversion. This lowers the required dynamic range of the ADC, and thus lowers the cost of the ADC. Second, the present invention allows more than one user to receive different channels at the same time. And third, it is possible according to the present invention to prevent an undesired signal from overloading the receiver.

[0028] Figure 2 is a more detailed schematic of one embodiment of the present invention, which is just one of many examples of implementing the block diagram of figure 1 and will be used to describe the three scenarios outlined above. In the example shown in Figure 2, two bandpass filters are shown. However, it should be noted that there it is possible to use more bandpass filters and only two are shown for a simplified explanation of the present invention. Like reference numbers between figures 1 and 2 represent like elements.

[0029] Referring still to Figure 2, a first tunable bandpass filter 14a has a tuning voltage $V_1$ for a first selection and a second tunable bandpass filter 14b has a tuning voltage $V_2$ for a second selection. The antenna 12 output can only deliver fixed power at a fixed position and fixed time across a fixed bandwidth. Therefore, at any moment, the tuner input circuits will drain maximum power from the antenna 12 at selected frequencies.

[0030] Figure 3 is a representation of the antenna power at the antenna output. Say for example, the first tunable bandpass filter 14a is tuned by a voltage $V_1$ for frequency $f_1$. The graph of Figure 4 shows the higher power at the selected frequency $f_1$ and the lesser power at $f_2$, the unselected frequency. Likewise, Figure 5 shows the power for the second tunable bandpass filter 14b that is tuned by voltage $V_2$ for frequency $f_2$. There is considerably less power at $f_1$, the unselected frequency, and high power at the selected frequency $f_2$.

[0031] In the case where both of the tunable bandpass filters are tuned to the same frequency, shown in Figure 6, the present invention is capable of drawing maximum power from the antenna. When the filters are tuned close to each other, the bandpass filters are combined. In the present example, a double bandpass filter is formed to provide maximum reception of the selected channel and maximum rejection of undesired channels.

[0032] In the case where the filters are tuned to different frequencies for "listening" to more than one channel at a time, the output shown in Figure 7 is achieved by the present invention. "Listening" in the present invention may be an occupant who is actually listening to a broadcast channel, or it may be a different user, such as a device that is receiving RDS data broadcast over a channel. In any event, with the present invention each frequency draws equal power

thereby, providing equal reception at each channel, independent of the signal strength.

[0033] Automatic gain controls [$AGC_1$] and [$AGC_2$] along with a respective amplifier A1 and A2, can be provided at the filter 14a and 14b outputs in order to substantially equalize the signals before summing and digitization. In this regard, the strong signals will be balanced with the weaker signals thereby preventing the strong signals from overriding the weaker signals. Consider the case where the stronger signal exists at the input to amplifier A2 and the weaker signal exists at the input to A1. In order to balance the signals, the automatic gain control [$AGC_2$] and the amplifier A2 should be set at a relatively higher gain reduction, and the automatic gain control [$AGC_1$] and the amplifier A1 should be set at a relatively lower gain reduction.

[0034] A further application of the multiple bandpass system of the present invention is to reject strong undesired channels that could overload the system. In this application, one or more bandpass filters can be tuned to one or more of the undesired channels to absorb the undesired signals. In this case, shown in the series of figures 8a through 8f, the first bandpass filter is tuned to a desired frequency having a weak signal strength. Figure 8a shows the air signal strength at the antenna for each of a desired frequency $f_1$ and an undesired frequency $f_2$. Frequency $f_1$, the desired frequency has a weaker signal than the undesired frequency $f_2$.

[0035] The first tunable bandpass filter is tuned to the desired frequency $f_1$. Figure 8b shows the power at the output of the first tunable bandpass filter. However, because the undesired signal is so strong, it still appears more powerful than the signal at frequency $f_1$. In order to strengthen the signal at $f_1$, it is necessary to absorb the undesired signal at frequency $f_2$. This is accomplished by tuning the second bandpass filter to $f_2$. Figure 8c shows the power at the output of the second tunable bandpass filter.

[0036] Figure 8d shows the power output after the first automatic gain control [$AGC_1$] and amplifier A1. The second automatic gain control [$AGC_2$] is turned to the maximum gain of its gain control range. For example, the automatic gain control may have a gain control range of 20 dB. The minimum gain setting for [$AGC_2$] and amplifier $A_2$, selects the undesired signal for rejection. Figure 8e shows the output power after the second tunable bandpass filter and amplifier.

[0037] Figure 8f shows the output provided to the receiver in which the signals at $f_1$ and $f_2$ are modified before being processed. The present invention effectively reduces the strength of the undesired signal, and improves the strength of the desired signal.

[0038] The bandpass filters and automatic gain control being set in accordance with the present invention significantly increase the dynamic range of

the signal strength and desired frequencies before digitization is required, thereby eliminating the need for multiple ADC's. In addition, there is no need for an intermediate frequency, eliminating the need for multiple local oscillators and their associated mixing hardware.

[0039] Figure 9 is a flow chart of the method 100 of the present invention. An analog RF signal from the desired bandwidth is received 102 by the antenna. At least two tunable bandpass filters are used to select 104 a desired channel on the desired bandwidth. The channels can be different from each other, but are selected from a single broadcast band, i.e. AM or FM. As stated above, the number of bandpass filters is typically related to the number of users. One skilled in the art is capable of determining a practical number of filters.

[0040] The filtered output is summed 106 into one signal. The summed signal is digitized 108 in a single ADC and delivered 110 to a digital tuner where the desired frequencies are made available to the vehicle's occupants.

[0041] In an alternative embodiment, the filtered outputs are made to have substantially equivalent levels 112 by automatic gain controllers. This feature ensures that the weaker signals are not overridden by stronger signals and that each channel chosen is equal in strength.

[0042] The present invention also has utility in a data logging application. Data logging typically requires two tuners. One tuner is used for listening to a single channel; the other tuner scans other frequencies looking for predetermined data. With the system and method of the present invention, data logging can be accomplished using a single tuner. One bandpass filter can be used to tune to a particular channel for listening, while one or more of the remaining bandpass filters can be used to scan available channels.

[0043] The invention covers all alternatives, modifications, and equivalents, as may be included within the spirit and scope of the appended claims.